GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. _____

Project No. E-19-630 GTRI/~~GTX~~ DATE 3 / 6 /84

Project Director: Dr. M. Marek School/~~Lab~~ ChE

Sponsor: Calcusearch, Inc.

Type Agreement: Standard Research Project Agreement No. E-19-630

Award Period: From 2/27/84 To 9/30/84 (Performance) 6/30/84 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 34,402	$ 34,402
Funded:	$ 34,402	$ 34,402

Cost Sharing Amount: $ VPR account will be set up for cost-sharing Cost Sharing No: *

Title: Investigation of Re-usable Hot Top Technology

ADMINISTRATIVE DATA OCA Contact Lynn Boyd x4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

Mr. Chuck Childs, General Manager
Calcusearch, Inc.
Advanced Technology Development Center
Georgia Institute of Technology
430 Tenth Street, NW
Atlanta, GA 30318

Defense Priority Rating: n/a Military Security Classification: n/a

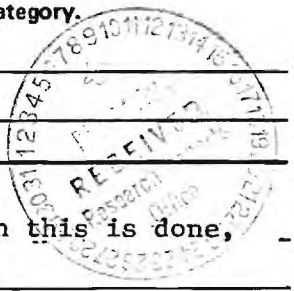
(or) Company/Industrial Proprietary: non-disclosure agreement dtd. 2/27/84 see articles 10, 11, 12, 13 of agreement.

RESTRICTIONS

See Attached ------ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with none authorized or proposed.



COMMENTS:

* Cost sharing account will be set up in the amount of $17,201. When this is done, copy of paperwork and budget amendment should be forwarded to OCA.

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GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 3/6/86

Project No. E-19-630 School/Lab ChE

Includes Subproject No.(s) N/A

Project Director(s) M. I. Marek GTRC / ~~GIT~~

Sponsor CALCUSEARCH

Title Investigation of Re-usable Hot Top Technology

Effective Completion Date: 9/30/84 (Performance) _____ (Reports)

Grant/Contract Closeout Actions Remaining:

- [X] None — No Reports Due
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____ Continued by Project No. _____

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INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

by

Miroslav Marek

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GEORGIA INSTITUTE OF TECHNOLOGY

Atlanta, Georgia 30332

PROGRESS REPORT
Project E-19-630
2/27/84 - 3/31/84

OBJECTIVE

The objective of the project is to evaluate the Vallak Re-usable Hot Top Technology in ingot steel casting.

PROJECT SCHEDULE

The project is divided into four phases as follows:

Phase I - Feasibility Study
Phase II - Demonstration Site Selection
Phase III - Site Demonstration
Phase IV - Final Report

This Progress Report covers Phase I of the project.

SPECIFIC AIM (Phase I)

The aim of Phase I of the project was to evaluate the technical background of the Re-Hot Top Technology, explore the potential interest in the Vallak Re-Hot Top in selected parts of the U.S. steel industry, and to estimate the potential of its application in the U.S.

WORK PLAN (Phase I)

A. A review of pertinent literature and patents concerning the Vallak Hot Top Technology.
B. Contacts with metallurgists in the steel plants; discussion of the present technology and potential interest in the Vallak Re-Hot Top.
C. A visit to steel plants in Europe to examine the current use of the Vallak Re-Hot Top and the industrial experience with this technology.

WORK SUMMARY

A. Literature Review

The literature reviewed included standard metallurgical texts, United States Steel Handbook "The Making, Shaping, and Treating of Steel," and statistical literature published by the American Iron and Steel Institute. Also reviewed was the following patent literature:

U.S. patent #3,766,965 (1973), Method of Hot Topping of Ingot Mold (Enn Vallak),

U.S. patent #3,929,183 (1975), Method for Sealed System of Hot Tops, Ingot Moulds or a Combination Hot Top and an Arrangement for Said Sealed System (Hannes Vallak),

International Appl. No. PCT /EP79/00003 (1979), Improvements in or Relating To Casting Metal Ingots (Enn Vallak),

International Appl. No. PCT/EP80/00131 (1980), Ingot Mould Comprising a Hot Top Positioned Inside the Upper Part of the Mould and Process for Manufacturing Said Mould (Enn Vallak and Hannes Vallak), U.S. pattent applied for,

and supporting literature.

B. Industrial Contacts

The following main contacts have been made:

USS, Geneva Works, Geneva, Utah
Mr. Scott Keysir, Chief Metallurgist

USS, Homestead Works, Munhall, Pennsylvania
Mr. Charles Churchill, Chief Metallurgist

Atlantic Steel, Atlanta, Georgia
Mr. Alan Gorton, Quality Control

Atlantic Steel, Atlanta, Georgia
Mr. Frank Tippett, Superintendent

Dravo Engineers and Contractors, Pittsburgh, PA
Mr. Ken Caine

The Timken Co.,Canton, Ohio
Mr. James Stepanic, Meltshop

The Timken Co., Canton, Ohio
Mr. C. Phillip Wiagel, Director of Technology

Further contacts are being pursued.

C. Steel Plants in Europe

The following two steel plants, currently using the Vallak Re-usable Hot Top, have been visited on March 26-27, 1984:

Von Roll AG, Gerlafingen, Switzerland

Vallak Re-Hot Top discussed with Dipl. Ing. Klaus Langauer; Hot Top and mold examined on site.

Vereinigte Edelstahlwerke Aktiengesellschaft Werksgruppe (VEW), Kapfenberg, Austria

Vallak Re-Hot Top discussed with Mr. Gustav Forstner, Director, Dipl. Ing. Dr. mont. Rainer Tarmann, and Ing. Kurt Schwarz. Hot Top and mold examined on site; casting of steel in the mold equipped with the Vallak Re-Hot Top observed.

RESULTS AND DISCUSSION

A. Scientific and Technical Merit

The steel industry uses many different types of Hot Tops in casting ingots of deoxidized ("killed") steel. The Hot Top insulates the head of the ingot, and sometimes also supplies heat, to slow down the solidification of the steel in the head and create a reservoir of molten metal which feeds the solidifying and shrinking ingot in the mold. The most common Hot Tops have ceramic lining which is either prefabricated, or assembled before casting. The lining has to be replaced or repaired after each use. Another common type of a Hot Top uses a consumable lining which is exothermic and provides heat in addition to insulating the head of the ingot. Powders, usually exothermic, are used on the top surface of the ingot to insulate it and supply some additional heat. A much less common type of Hot Top uses electrodes to supply controlled heat to the ingot head.

The main disadvantages of the current technology are the manpower requirements for assembly or repair of the ceramic-lined Hot Tops, the relatively high cost of the non-reusable materials, and, in some cases, the detrimental effects on the quality of the steel because of contamination. Different Hot Tops produce ingots of different yield and quality. The electrode-equipped Hot Tops are costly in use because of the high consumption of electrical energy.

The Vallak Re-usable Hot Top eliminates many of the disadvantages of the conventional designs. The surface which comes in contact with the molten steel (the inner ring) is made of steel, so that no contamination occurs. A very efficient thermal insulation is provided by an air gap between the inner ring and the ingot head, which forms when the skin forms on the cast metal and the inner ring expands upon heating. The Hot Top can be designed to fit closely on the mold, eliminating surface

and segregation problems in the shoulder between the ingot and the head. Although topping powders can be used with the Vallak Hot Top, the Vallak Thermo Cover provides efficient insulation and a complete absence of contamination.

The discussions with the engineers in the steel plants in Europe which use the Vallak Re-usable Hot Top, and the observation of the casting of an ingot using the Vallak Hot Top at VEW, have confirmed that the device works as claimed by the inventors. The quality of the ingots was described by the engineers at both plants as at least as good as with the conventional Hot Tops. There are no serious problems in the application. The molten steel does not weld to the inner ring, as anticipated by some steel plant personnel. The VEW steel plant in Austria plans to convert 40% of its production of specialty steels (about 40,000 tons out of 100,000 tons production) to casting with the Vallak Re-usable Hot Top by the end of 1984.

On the negative side, there are only two Vallak Re-usable Hot Tops in use in steel plants now, one at Von Roll and one at VEW, so that the experience is limited. In both cases the production involves forging ingots. The inventors made tests with rolling ingots for SKF company in Sweden, but there are no Vallak Re-Hot Tops in production for this purpose. No analytical and metallurgical data are available for a comparison of the quality of the ingots produced with Vallak and conventional Hot Tops. The only testing of the ingots in either plant has been performed by ultrasonic techniques. At the VEW plant the engineers were able to reduce the level of molten steel in the head to a minimum needed for handling during stripping, but no evaluation of the potential improvement in the yield has been made. In one trial at VEW the ingot was rolled and a 3% cutoff at the top was achieved, but the determination was based only on ultrasonic examination of the bar.

There is a serious lack of data concerning the lifetime of the inner ring of the Vallak Re-usable Hot Top. Because of experimentation with different materials and designs, no ring has been used long enough to provide even a rough estimate of the potential life. More research is needed to optimize both the materials selection and the design.

B. Response from U.S. Steel Industry

The response to date, based on informal contacts at selected plants, has been promising but noncommittal. The plant metallurgists generally expressed interest and willingness to evaluate the device.

The most promising potential demonstration site so far is The Timken Company in Canton, Ohio, which makes about 750,000 tons of steel in Hot Tops annually. The plant engineers are currently considering a change in the Hot Top technology because of the problems with the quality of the ingots. According to the latest information the standard ingot weighs 7,300 lb, is 21.5 in. square at the top, and the mold is fluted. Using the current technology the Hot Top contains 11% of the molten steel (5-6% after solidification). Because of the high quality of the steel The Timken Company makes (ball bearing steel), an acceptance of the Vallak Reusable Hot Top at Timken would be a valuable recommendation for other steel plants.

Preliminary information from other steel plants also indicated potential interest, especially if a significant improvement in the yield can be demonstrated. Information from USS, Geneva Works, shows that the current top cutoff loss is about 14%, and an effort is made to reduce it to 10% using a modification of the current Hot Top technology. A reduction of the cutoff loss below 10% would make the Vallak Hot Top very competitive.

C. Potential Market

No definite data have been obtained for the total production of steel in Hot Tops in the U.S. There seems to be, however, a general agreement of information from individuals in the steel industry on the following rough estimates:

Total U.S. raw steel
production in 1984.....85,000 to 90,000 tons

Fraction made by continuous
casting.....25-35%

Fraction of ingot-cast
steel made in Hot Tops.....30%

Based on this information the total U.S. raw steel production in Hot Tops can be estimated to be between 16,500 and 20,000 tons in 1984.

CONCLUSIONS

Although Hot Tops can be considered a part of the outdated technology in view of the rapidly expanding continuous casting of steel, a transition period will exist in which ingot casting will continue to be a major factor in steel production. The introduction of more advanced technology, such as the Vallak Reusable Hot Top, can result in substantial savings for the U.S. steel industry and improve its competitiveness on the world market in the immediate future.

The Vallak Reusable Hot Top is scientifically sound; the steel plant production experience, although limited, has shown its practicality. Compared with conventional Hot Tops it represents a significant advance in the technology.

There is a serious lack of scientific evidence with respect to the yield and metallurgical quality of the ingots cast with the Re-Hot Top, as well as the lifetime of the Hot Top. Further research is needed to optimize the materials selection and design of the Hot Top. In spite of the lack of evidence, there is every reason to believe that the quality and yield will be better than with the conventional Hot Tops, but the difference cannot be quantitatively evaluated on the basis of the information available.

RECOMMENDATION

On the basis of the results of Phase I it is recommended to proceed with Phase II of the project - Demonstration Site Selection.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

by

Miroslav Marek

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PROGRESS REPORT
Project E-19-630
4/1/84 - 4/30/84

OBJECTIVE

The objective of the project is to evaluate the Vallak Re-usable Hot Top Technology in ingot steel casting.

PROJECT SCHEDULE

The project is divided into four phases as follows:

Phase I - Feasibility Study

Phase II - Demonstration Site Selection

Phase III - Site Demonstration

Phase IV - Final Report

This Progress Report covers Phase II of the project.

SPECIFIC AIM (Phase II)

The aim of Phase II of the project was to select the site or sites for the demonstration of the Re-Top Technology by direct negotiations with interested steel plants, and to prepare the demonstrations.

WORK SUMMARY

The following steel plants have been selected for the demonstrations:

The Timken Company, Canton, OH

(Contact initiated by Georgia Tech. Agreement has been reached and preparations for the demonstration are in progress)

Bethlehem Steel Corp., Bethlehem, PA (Headquarters)

(Contact initiated by Calcusearch; agreement reached, preparations for the demonstration are in progress)

United States Steel Corp., Pittsburgh, PA

(Contact initiated by Georgia Tech; agreement in principle reached, but personnel changes at USS require further negotiation)

RESULTS AND DISCUSSION

Following initial contacts and telephone discussions with Timken Company officials, a meeting was held on April 12 at Timken. Mr. Lanny Byrer, Process Metallurgist, headed the Timken group. Representing Georgia Tech was Dr. M. Marek. Calcusearch was represented by Mr. Charles Childs. Dr. E. Vallak and Mr. T. P. Etter represented Ferrox-LEM S.A.

In the discussion the visiting team explained the main features of the Re-Top System. The representatives of Timken Company expressed interest in the product and agreed with the demonstration. Several alternatives of ingot size were considered, the final decision to be made later after the inspection of the drawings by Ferrox-LEM S.A. The Timken team emphasized their interest in the quality of the shoulder between the ingot and the ingot head, and in the cleanliness and quality of the ingot. The metallurgical analysis will be performed on samples from billets following rolling of the ingots. The visiting team made a tour of the ingot casting and rolling facility.

Since the April 12th meeting further telephone discussions were held with Mr. Byrer of Timken Company, and the ingot mould drawing have been sent to Calcusearch. A tentative date for the demonstration has been suggested, but is subject of further negotiations.

On April 18th a meeting was held at the U.S. Steel Corporation, Homestead Plant, in Pittsburgh. The visiting team consisted of Dr. Marek (Georgia Tech), Mr. C. Childs (Calcusearch), and Mr. C. Musick (Re-Top USA, Inc.). The U.S.S. team was headed by Mr. Edward Bueche, Manager-Technical Service, Mon Valley Works, and included Mr. Saul Gilbert, Research Consultant, U.S.S. Technical Center. The visiting team explained the Re-Top technology and

answered the questions from the U.S.S. team. The U.S.S. team emphasized that their main interest was in a hot top system which allowed a variation in the ingot size depending on demand. An agreement in principle was reached to make a demonstration of the Re-Top Technology, the site of demonstration and size of ingot to be selected in further negotiations and contacts by telephone. The metallurgical tests may include splitting of an ingot and taking core samples, or a metallurgical analysis following rolling.

Since the April 18th meeting a personnel change has been made at U.S. Steel Corp., and Mr. Ball replaced Mr. Bueche as the head of the U.S.S. team. This changes will require a second meeting at the U.S.S. plant.

The negotiation with Bethlehem Steel Corp. has been conducted by the Calcusearch team, which included, in the first visit, Dr. Vallak and Mr. Etter from Ferrox. Georgia Tech has not been, so far, represented. An agreement has been reached to make a demonstration at one of the Bethlehem Steel Corp. plants, and the preparation is in progress. The demonstration date has been tentatively set for the week of June 18.

During the remaining time before the demonstrations, the Georgia Tech project personnel will prepare a detailed plan of the metallurgical analysis of the ingots. Because of the timing and increased number of planned demonstrations, an extension of the project period to 9/30/84 has been requested.

CONCLUSIONS

The negotiations to perform steel plant demonstrations of the Re-Top technology have been successful. At least two, and probably three demonstrations will be made in June/July 1984.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

by

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PROGRESS REPORT
Project E-19-630
5/1/84 - 5/31/84

PROGRESS REPORT

5/1/84 - 5/31/84

The main activity during the reported project period involved discussions with the technical personnel of the selected steel plants in preparation for there demonstration tests of the Vallak Re-Top. The meetings in which the Principal Ivestigator (GaT) was involved included the following:

May 9: Discussion with Mr. Dave Bull at the US Steel Homestead Plant in Pittsburgh. Mr. Bull replaced Mr. Bueche as the head of the USS team and the meeting served to acquaint him with the Vallak Re-Top.

May 15: Discussion with the technical personnel at the Bethlehem Steel Corp. plant in Johnstown, PA. An agreement was reached to conduct the demonstration tests of the Re-top at the Johnstown plant in June. The discussion concerned mainly the technical details of ingot mold selection and Re-Top design.

May 16. Discussion with the technical personnel at the Timken Co. plant in Canton, OH. An agreement was reached to conduct a demonstration test in July. The discussion concerned similar questions as at Bethlehem Steel.

The Re-Tops to be used in the Bethlehem Steel and Timken trials will be designed and manufactured in Switzerland and

shipped by air to the US. The Principal Investigator (GaT) will participate in the initial tests at each plant. At both Bethlehem Steel Corp. and Timken Co. the metallurgical evaluation of the steel will be performed by the plant laboratories.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

by

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PROGRESS REPORT
Project E-19-630
6/1/84 - 6/30/84

PROGRESS REPORT

6/1/84 - 6/30/84

During the reported period the first US demonstration tests of the Vallak Re-Top were conducted on June 18 to June 28 at the Bethlehem Steel Corp. plant in Johnsttown, PA. The Principal Investigator (GaT) witnessed the casting of the ingots on June 18 and June 19. The Re-Top used in these tests had been designed and manufactured in Switzerland. Mold types SY and ST were used, and the steel grades included medium to high carbon and low allloy steels. The Re-Top was used with the Vallak Thermal Cover. No exothermic powders were used except in Test 8 in which 2 pounds of aluminum were added to the mold after pouring. A total of 10 tests were performed. The ingots were rolled into blooms and square billets, which were subjected to a etch tests, segregation tests, and cleanlinness tests.

TEST RESULTS

Contrary to expectations, the quality and yield of the steel made with the Re-Top were inferior to those obtained with conventional Hot Tops. The main problems included excessive piping and segregation. Design changes of the Re-top will be necessary to overcome the shortcomings. The first modifications will include a change in the taper of the inner liner to a smaller value, and an increase in the amount of insulation. The purpose of these changes is to move the pool of liquid steel

which exist withon the head of the ingot before final solidification away from the Top/mold junction upwards. The newly designed Re-Top will be manufactured in the US under the Calcusearch/Georgia Tech supervision.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

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PROGRESS REPORT
Project E-19-630
7/1/84 - 7/31/84

PROGRESS REPORT

7/1/84 - 7/31/84

During July, 1984, a second demonstration test of the Vallak Re-Top
was conducted at Timken Co. in Canton, OH. The Prinicpal Investigator (GaT) witnessed the initial tests. The Re-Top used in these trials had been designed and manufactured in Switzerland. It was used with the Vallak Thermal Cover and no exothermic powders were used in the initial tests.

TEST RESULTS

Similarly to the results at Bethlehem Steel Corp., the Re-Top produced ingots with excellent surface quality of the ingot head and head/body junction, but unacceptable piping. Design modifications will be necessary to improve the quality of the ingots.

OTHER ACTIVITIES

The results at both Bethlehem Steel and Timken showed that the Re-Top had not been sufficiently tested in Europe, and that a more detailed analysis of the operating conditions, and appropriate design changes, will be necessary to improve its performance. The steel plants involved in the initial tests are still interested in the Re-Top because of the potential of

cleaner steel and environment as a result of the elimination of the topping powders, and potential savings because of the reusability of the Re-Top. Therefore, an extensive literature search has been initiated by the Pricipal Investigator (GaT) concerning the solidification of ingots, segregation, and effects of Hot Tops. The work in the following project periods will include a more detailed analysis of the effects of the design variables, and is expected to result in suggestions of design modifications.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

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PROGRESS REPORT
Project E-19-630
8/1/84 - 8/31/84

PROGRESS REPORT

8/1/84 - 8/31/84

In August, 1984, a demonstration test was conducted in the third steel plant, the Duquesne plant of the U.S. Steel Corp. in Pittsburgh, PA. The test was made on August 28-30. The Re-Top used in this test was designed by Calcusearch and manufactured in Norcross, GA. To obtain experimental data for a more detailed analysis of the performance the Re-Top was equipped with probes for the temperature measurements of the inner and outer liner during casting and solidification. The Principal Investigator (GaT) actively participated in the design and preparation of the measurements. Temperature data were succesfully obtained during the test, and will be analyzed in the following period. The metallurgical results for the first ingot have not become available by the end of the reported period.

The Principal Investigator also participated in the analysis of the thermal performance of the Re-Top, which resulted in the development of a mathematical model which will be used in the future work. The major result of the initial analysis is that the heat absorption in the inner liner is substantial and may be a major factor in the inferior performance of the Re-Top, especially with relatively small ingots. As a result of this finding, a new, thinner liner, made of an oxidation and creep resistant stainless steel, will be used in the forthcoming tests at Timken Co.

E-19-630

INVESTIGATION OF RE-USABLE HOT TOP TECHNOLOGY

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PROGRESS REPORT
Project E-19-630
9/1/84 - 9/30/84

PROGRESS REPORT
9/1/84 - 9/30/84

In September, 1984, since no request for participation in demonstration tests or other development work was made by Calcusearch, the activity of the Principal Investigator was limited to a continuation of the literature search and theoretical analysis of ingot casting with hot tops. Additional literature was compiled, related to the performance of traditional hot tops, the effects of variables, reported mathematical models, segregation, etc.

The review of literature has shown that an ingot with a hot top is an extremely complex system, that has not been adequately described even by the mathematical models outlined (but not published) so far in the academic literature. Factors, such as dimensions, shape, materials, convection currents, two-dimensional heat flow, etc., must be taken into consideration. For the reusable hot-top, the heat absorption in the liner becomes an additional factor in the analysis. Furthermore, the segregation patterns depend on the composition and solidification characteristics of the steel cast in the hot-top.

A conclusion is made at this time that it is unlikely that the Re-usable Hot Top can be modified to perform according to expectations by making design changes based on educated guesses. A thorough mathematical analysis, combined with experimental measurements on suitable models, would be necessary to optimize the performance of the Re-usable Hot Top. Such an analysis seems to be feasible, but would be lengthy and expensive. It is questionable if a large scale effort of this type is justifiable, in view of the decreasing use of ingot casting in the steel industry.